METHOD OF MANUFACTURING DISPERSION STRENGTHENED COPPER AND/OR HYPER-NUCLEATED METAL MATRIX COMPOSITE RESISTANCE WELDING ELECTRODES

CROSS-REFERENCE T0 RELATED APPLICATION

[0001] This Application claims priority from U. S. Provisional Patent Application Serial Number 60/426,435, filed on November 14, 2002, the disclosure of which is hereby incorporated in its entirety herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention:

[0002] This invention relates to improvements in the method of manufacturing welding electrodes. More particularly, this invention is directed to provision of a novel, more cost effective method of manufacturing dispersion strengthened copper and/or hyper-nucleated metal matrix composite resistance welding electrodes directly from a sintered powdered metal compact pre-form.

2. Description of Prior Art:

DSC and HNMMC Material Production:

[0003] Dispersion strengthened copper (DSC) is a non-ferrous metallic composite material consisting of essentially pure elemental copper powder with aluminum oxide finely dispersed throughout its metal matrix, although other elements may admixed therewith. Hyper-nucleated metal matrix composite (HNMMC) is a similar material except that the copper matrix contains, in addition to the Al_2O_3, very small quantities of various other additional elements that promote the presence of a much larger quantity of nucleation sites within the metal matrix than conventional DSC. Both HNMMC and DSC are produced by

gas atomizing a copper-aluminum alloy into a powder form and exposing the powder to a series of heat treat processes under various controlled atmospheric conditions. The heat treat process converts the aluminum in the alloy to aluminum oxide. DSC can also be made by a process of mechanically alloying pure cooper and Al_20_3 powders. Mechanical alloying is not an appropriate process to use to produce HNMMC materials. Dispersion strengthened cooper and methods of manufacture therefore are well known in the prior art. See, *inter alia*, U.S. Patent Nos. 5,567,382 and 5,551,970.

[0004] DSC and HNMMC material exhibit the ability to retain its room temperature physical properties at temperature levels closely approaching its melting point. This ability is especially suitable for applications in devices such as resistance welding electrodes.

[0005] Resistance welding electrodes typically operate, in service, under severe loads at very high temperatures. This limits the useful life of electrodes made from more conventional welding electrode materials.

[0006] Thus, the art has turned to metal matrices such as DSC and HNMMC for manufacturing resistance welding electrodes. In manufacturing electrodes from these materials usually the metal powder is converted into a solid form that can be cold-formed into the desirable electrode shape through intermediate processing steps.

[0007] Generally, the conventional method employed heretofore to convert HNMMC and/or DSC powder, and alloy derivatives thereof, into a form suitable for cold forming electrodes has been to hot extrude a billet of the metal powder in an extrusion press at a temperature marginally below its melting point, because HNMMC and/or DSC cannot be cast into an ingot, as once it is melted, the aluminum oxide is liberated from the matrix and floats to the top of the melt as slag.

[0008] According to the prior art processes the HNMMC and/or DSC powder is first

compacted into an open-ended pointed pure copper billet can. With as high powder packing density as possible, the close proximity of the copper particles to one another enhances the diffusion bonding mechanism that locks the particles together during the extrusion process. The copper billet can has a spun-formed point on its closed end so that it nests securely into a correspondingly shaped chamber in an extrusion press used in the follow-up extrusion operation.

[0009] The densely packed HNMMC and/or DSC powder is then sealed into the copper can to form a billet by welding a copper cap onto its open end. The billet is then heated to approximately 75% of its melting point, and placed into the forming chamber of an extrusion press. It is then extruded through a die into the form of a long rod having a circular cross sectional area.

[0010] The extrusion process causes the individual HNMMC and/or DSC powder particles to diffusion weld to one another forming a solid HNMMC and/or DSC material in the form of a long coiled rod. Since the copper "billet can" was used to contain the powders in the chamber of the extrusion press, it is extruded along with the HNMMC and/or DSC powders and ends up as a 0.015 inch to 0.020 inch thick pure copper cladding (skin) over the entire outer surface of the hot extruded rod. The extrusion process produces a material with a co-axial, anisotropic, fibrous grain structure that necessitates potentially costly special accommodations in the subsequent manufacturing process employed to produce resistance welding electrodes. These process accommodations involve reconfiguring the grain structure of the welding tip portion into a non-fibrous isotropic orientation, and are well known in the prior art. See, U.S. Patent No. 4,045,644.

[0011] Because of the high mechanical and thermal loads associated with a resistance-welding operation, non-alloyed pure copper has a tendency to melt and fuse to a

steel workpiece during a welding operation. This is especially true when resistance-welding zinc coated (galvanized) steels, such as those commonly used in automotive vehicle body fabrication. Consequently, the copper skin layer has to be removed from the electrode face prior to its use.

[0012] Finally, to render it suitable for the cold forming of electrodes, the HNMMC and/or DSC rod must be pickled to remove any scale and drawn through a sizing die to dimensionally qualify its cross-sectional area. Representative of the process is that disclosed in U.S. Patent No. 5,914,057, the disclosure of which is hereby incorporated by reference.

[0013] With the current method of fabrication, coils of precision drawn HNMMC and/or DSC rod are fed into a 5 to 6 stage cold heading machine. This is a high volume production-forming machine that cuts a measured length of rod from the HNMMC and/or DSC coil and feeds it through a progression of forming dies to produce a net shaped resistance-welding electrode.

[0014] Once the electrode is formed, a secondary machining operation is required to remove the copper skin from the working surface of the electrode that contacts the workpiece.

[0015] It is to be appreciated from the preceding that the conventional techniques for manufacturing resistance-welding electrodes have certain inherent drawbacks and multiple processing stages.

[0016] In addition to cold forming, net shape parts may be made from various alloys in a single step process involving high speed injection molding of semi-solid thixotropic alloys. Thixomolding is based on the principle that alloys with complex phase diagrams melt over a defined temperature range. An alloy transforms from a solid into a semi-solid as it is heated passed the melting point of the alloy component with the lower melting point and

terminates as a liquid once the melting point of the higher melting point component has been reached. In the semi-solid state the alloy exists as a slurry of metallic crystals suspended in a molten metal liquid. This allows these materials to be injection molded under pressure similar to the way plastics are molded. Advantageously, the thixomolded process produces net or near net shape parts

[0017] According to the present invention as detailed below, desirably, HNMMC, DSC, or other non-ferrous powder is converted directly into a form suitable for cold forming, or semi-solid molding, and then into a final shape.

SUMMARY OF THE INVENTION

[0018] According to this invention, a method of manufacturing dispersion strengthened copper and/or hyper-nucleated metal matrix composite resistance welding electrodes comprises:

compacting a powdered metal into a desired pre-form densified compact shape,

sintering the compact shape, preferably under an inert atmosphere, and

cold forming or pre-heating and thixomolding, as required, the resultant sintered powdered metal compact shape into its final net shaped finished electrode form.

[0019] If the net shape final electrode form can be achieved directly in the compacting and densifying step, then the subsequent step of cold forming is not necessary.

[0020] Although not necessarily limited to any specific powdered metal material in its application, this process is especially suitable for making resistance welding electrodes from dispersion strengthened copper (DSC) and/or hyper-nucleated metal matrix composite (HNMMC) powdered material. However, it is contemplated that the present invention can be used with other non-ferrous powder metals, including, *inter alia*, various conventional

copper-based welding alloys, such as copper-chrome-zirconium, copper-zirconium, beryllium-copper and the like.

[0021] According to another important aspect, this invention is directed to a product manufactured by the above process.

[0022] According to this invention, there is provided a method of manufacturing a resistance welding electrode, comprising the steps of:

preparing an amount of metal powder, wherein said metal powder is dispersion strengthened copper and/or a hyper-nucleated metal matrix composite,

compacting and densifying the metal powder into a pre-form having a desired shape, said compacting and densifying producing a pre-form having a density in excess of 85% of theoretical density,

sintering the pre-form, preferably under an inert atmosphere, and

shaping the resultant sintered metal powder pre-form into a final net shaped finished electrode form.

[0023] According to this method, the step of shaping includes cold forming, and a semi-solid molding process. In one aspect, the semi-solid molding process comprises thixomolding.

[0024] Further in support of the thixomolding process and according to this method, the preparing of an amount of metal powder includes introducing a second phase by mechanically alloying a major amount of the dispersion strengthened copper and/or hyper-nucleated metal matrix composite with a minor amount of other lower melting point elemental non-ferrous alloy powders prior to compacting and sintering. The step of sintering is carried out at a temperature sufficient to wet out a portion of the minor component within the alloy pre-form, the sintering being at a temperature from about 1550°F to about 1,850°F.

[0025] Preferably, the minor amount of other elemental non-ferrous alloy powder is selected from the group consisting of silver and in an amount sufficient to change a desired physical property of the pre-form.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0026] As noted hereinabove, the present invention has particular applicability to DSC and/or HNMMC metal powders, but is applicable to other non-ferrous metal powers, including alloys and composites. However, for purposes of the ensuing description reference is made to DSC and HNMMC, although these other powder metals are within the purview hereof.

[0027] The method of manufacturing herein involves placing a measured amount of HNMMC and/or DSC powder or other metal matrix into a compaction die of a pre-determined desired shape. According to this method, or process, the powder or metal matrix material is prepared, using a conventional process. The physical property of the material is modified, as required, by mechanically alloying with other elemental or alloy powders to achieve a desired result.

[0028] The powdered metal is compacted (pressed) into a desired pre-form shape. Generally, the die compacts the powder at a pressure or load of at least 50,000 psi and higher which necessary to achieve in excess of 85% theoretical density. The die is configured to compact the powder into the desired final form of the product, which is, in its simplest form, an appropriately shaped pre-form, and in its most advanced state, a fully formed, net shaped electrode.

[0029] The pre-form shape (or compact) is then placed in a sintering furnace, heated at a temperature of about 1550°F to about 1,850°F, and sintered in an inert or reducing atmosphere. Generally, an argon, xenon, or hydrogen atmosphere is used. Sintering will

generally extend for a period of about 60 to about 120 minutes, depending on the desired configuration and size of the pre-form shape.

[0030] The application of heat, or sintering, results in a bonding of particles in the mass of metal powder by molecular (or atomic) attraction in the solid state. Further, sintering causes strengthening of the powder mass, normally resulting in densification and recrystallization due to material transport.

[0031] The sintered pre-form shape (or compact) may be placed into a die cavity of the desired configuration and cold formed into its desired final shape.

[0032] The shape of the resultant powdered metal compact is then in its final net shaped finished electrode form.

[0033] As an alternative, a suitably formulated HNMMC and/or DSC alloy derivative can be used, as a feedstock, and semi-solid molded (i.e., thixomolded) directly into the desired final form. According to this alternative process of making a resistance welding electrode, a supply of suitably prepared metal powder, preferably HNMMC and/or DSC is mechanically alloyed with silver to introduce a second phase, and sintered into a billet.

[0034] The billet is then heated to a semisolid state where it is approximately 60% solid particles and 40% liquid. The billet is then introduced into the injection chamber of an injection molding machine to be molded into a preform shape for subsequent cold forming or if desired into a final net shape. The apparatus is not shown as known by those skilled in the art.

[0035] In particular, the part thus molded may be in the form of a rod, such as a resistance welding electrode.

[0036] It is readily apparent that in accordance herewith, DSC and/or HNMMC powder is readily converted into a form suitable for cold forming, or semi-solid molding (i.e., thixomolding), into a final shape by pre-forming and, then, sintering.

[0037] Desirably and advantageously, the present process eliminates the need for the powder to go through the various stages of packing and sealing it into a copper billet can and then hot extruding the billet in an extrusion press to form HNMMC and/or DSC rod. Further, the method according to this invention eliminates the secondary machining operation on the finished electrode to remove the pure copper cladding.

[0038] The subsequent cold forming process can be less costly as the method according to this invention produces a material that already exhibits a non-fibrous, isotropic orientation, without any special provisions having to be made to achieve this required grain structure.

[0039] Finally, as a result of the present method, the resultant pre-form compact, being formed directly from powders, will not be encapsulated with the pure copper skin that results when the billet can is hot extruded along with the HNMMC and/or DSC powder.

[0040] Process modifications to the physical properties of the pure HNMMC and/or DSC material can be introduced through the mechanism of mechanical alloying. Other elements in powdered form may be blended with the HNMMC and/or DSC material to effect the desired changes in the ,material properties of the finished material.

[0041] For example, a two phase HNMMC and/or DSC alloy, suitable for semi-solid molding (i.e., thixomolding) can be treated by mechanical alloying various percentages of a pure silver (Ag) powder with the original HNMMC and/or DSC powder. Changes to other physical properties, such as electrical conductivity, thermal conductivity, coefficient of thermal expansion, etc., can also be affected with precision.

[0042] While various embodiments of the present invention have been described in some detail, it is apparent that modifications and adaptations of those embodiments will occur to those skilled in the art. However, it is to be expressly understood that such modifications and adaptations are within the spirit and scope of the present invention.